Computed tomography angiography (CTA) of the coronary arteries is a useful non-invasive tool to rule out significant coronary artery disease (CAD) in many clinical situations. Recent guidelines of stable CAD\(^1\) and non-ST segment elevation myocardial infarction\(^2\) endorse the use of CTA in symptomatic patients with low to intermediate likelihood of the disease, given the particularly high negative predictive value of the technique. However, in patients with high pre-test likelihood of CAD, the technique is not recommended, and one of the reasons is the high probability of coronary calcification in these patients, which interferes with the analysis of the images and reduces the specificity and negative predictive value of CTA\(^3\)\(^-\)\(^6\).

The introduction of Aquilion ONE™ 320-row CT scanner, and later the Aquilion ONE™/ ViSION Edition with a maximum fastest rotation time of 0.275s, have it made possible to obtain a non-invasive coronary angiography in a single heart beat and several studies have demonstrated its high diagnostic accuracy in the depiction of epicardial coronary stenotic lesions\(^7\),\(^8\). Despite technological advances in CT, improving both spatial and temporal resolution, there are still several limitations due to increased heart rate, presence of small stents (less than 3 mm diameter), or extensive coronary artery calcification. Recently, Toshiba has developed a new application (Coronary Subtraction) to allow the subtraction of calcium and metal stents in the coronary arteries to improve the diagnostic performance in these clinical scenarios.

Coronary subtraction CT requires two scans, one pre-contrast and one post-contrast. The subtraction of three-dimensional (3D) CTA volumes is significantly more challenging than the two-dimensional (2D) subtraction performed in X-Ray digital subtraction angiography (DSA). Subtraction in two dimensions only requires shifting of the mask image in two axes: x and y. In 3D volumes, not only manual shifting of the mask in three axes (xy and z), but also rotational movement is required. The fact that the two studies have to be performed consecutively implies that respiratory, pulsatile and spatial motion potential changes can lead to volumes of data with somewhat different spatial relationships between bony structures and calcified or stented arteries. Coronary Subtraction can be performed in two breath-hold or in a single breath-hold (Figure 1).

The non-contrast CTA volume is then subtracted from the contrast-enhanced CTA volume, removing the calcium/metallic content of coronary arteries. To obtain an accurate registration of two volumes and minimize misregistration artefacts, the single breath-hold methodology was chosen. After pre-oxygenation with low-flow oxygen and immediately after contrast injection, a non-contrast scan and a contrast scan with
a z-coverage of up to 16 cm was performed in the same breath-hold. Prospective ECG-triggering was used with a variable exposure window depending on the heart rate. Coronary CTA analysis was performed on an off-line workstation (Vitrea Fx; Vital Images).

Three clinical cases from daily practice are presented to illustrate how the Coronary Subtraction application works and its correlation with the invasive coronary anatomy seen by an invasive catheterization.

CASE 1
51 year-old male, active smoker with hypertension, type II diabetes mellitus and hypercholesterolemia. Chronic ischemic heart disease previously revascularized with stents in left main and proximal to mid left anterior descending artery (2008). During the last month, he presented with atypical chest pain unrelated to physical effort. Baseline ECG did not show repolarization abnormalities.

Cardiac computed tomography angiography (CTA) showed previous implanted stents, with extensive metal artefact, making an assessment of neointimal hyperplasia or de novo atherosclerosis within the stents difficult (Figure A). After coronary subtraction, a vessel without any significant lesion could be observed (Figure B), as confirmed in a further invasive coronary angiography (Figure C).

CASE 2
69 year-old male, past smoker with hypertension and moderate chronic renal failure with a glomerular filtration rate of 40 mL/kg/min. No previous cardiac history. During the last weeks, he presented with atypical chest pain and an inconclusive exercise ECG (subtle changes in cardiac repolarization without associated angina).

Cardiac computed tomography angiography (CTA) showed a high degree of calcification in the left anterior descending artery that impeded the assessment of the wall lumen in these segments (Agatston score 845) (Figure A). After coronary subtraction, a vessel without any significant lesion could be observed (Figure B), as confirmed in a further invasive coronary angiography (Figure C).

CASE 3
64 year-old male, past smoker with hypertension and hypercholesterolemia. Chronic ischemic heart disease with previous inferior myocardial infarction and stenting of right coronary artery (RCA). After this he presented with unstable angina in the context of a total chronic occlusion at the site of the stent. Again, he was revascularized with bioabsorbable vascular scaffold. Six months later, the patient was referred for a CTA to check this last revascularization procedure.

Cardiac computed tomography angiography (CTA) showed a patent stent in the proximal RCA and focal calcification in the distal segment of the RCA, making it impossible to rule out significant stenosis in this segment (Agatston score 530) (Figure A). After coronary subtraction, an RCA without significant stenosis was observed (Figure B), subsequently confirmed with an invasive coronary angiography (Figure C).
CONCLUSIONS

The Toshiba Coronary Subtraction application is a promising tool to minimize calcium and metallic artefacts, as these three clinical cases have exemplified. Coronary calcium subtraction may improve the diagnostic accuracy of CTA, especially in those patients with extensive calcifications or small stents. More studies are needed to validate this diagnostic tool and find out what role this could have in clinical practice.

References
- Subtraction Coronary CT Angiography for the Evaluation of Severely Calcified Lesions Using a 320-Detector Row Scanner, Yoshioka K & Tanaka R, Current Cardiovascular Imaging Reports, 2011; 4(6):437-446

Bibliography